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A proposal of an index to measure press-through package design similarity

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Abstract

In this study, we proposed the distances of PTP sheet designs to measure their similarities. Under the assumption that the design repeats in the direction of row, it was decomposed into the parts of repetition unit. We employed template matching to obtain the best matching of the parts, and defined intermediate expressions of the designs to absorb the aperiodicity in the designs of the parts. We defined two distances, the extension of Euclid distance of the intermediate expressions in *CIE L*a*b** combining low pass filter in frequency domain, and the distance to measure the difference of the shifts. We calculated the distances for each pair of 198 PTP designs, and searched the designs that have short distance to randomly selected input designs. As a result, for three input images, we could extract PTP sheet designs similar to the inputs. It was also found that, if the ratio of forecolor part to background color part is small, the distance tends to have small value. Because of this, it is necessary to limit the use of d_{int} to search PTP sheet images which is similar to an input image.

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Keywords: PTP sheet design; Medical safety; Image processing; Similarity

1. Introduction

Proper use of proper drugs prevents medical accidents which originate from drugs. There are many causes that inhibit proper drug use, and confusing packages of drugs are one of major causes of mixing-up the drugs. It was reported that there were 16 incidents in Japanese pharmacies which originated from the similarity of tablet packages in 2011.

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In order to prevent accidents caused by confusing packages, Ministry of Health, Labour and Welfare in Japan discusses and adopts countermeasures, including submittance of notices. Press-Through-Package (PTP) sheets is a packaging unit of medical drug tablets. There is, unfortunately, no systematic measure to identify what PTP sheets are similar to each other. The reason why there is no systematic measure is the lack of a quantitative measurement of packages' similarities.

We assumed that the busy situation of pharmacists makes them roughly see the designs and get confused for similar ones. It is known that, for pharmacists, it takes only one second to see the backside of a PTP design during preparing drugs [1].

In our past study [2], we employed Fourier analysis to the periodical design of PTP sheets to extract their features. Since periodicity of the design is two dimensional, we applied two dimensional Fourier transform to the design. From the result, we clarified that we can separately deal with the atom part of design (prototile) and the periodicity of its copies. Under the assumption of busy situation, we employed rectangular approximation of a prototile to realize course-graining and compared it to the original prototile. The result showed that the transformed images in low frequency region hold information to distinguish/identify designs in prototiles. However, we limited ourselves to discuss gray scale PTP sheet designs and did not clarify how to measure the extent of similarity of PTP sheets.

In this study, we extend the above study to take account of color distribution in PTP sheets and propose their similarity index. A color in each pixel is mapped to a point in *CIE L*a*b** color system. We assume the design is the union of copied parts assigned to each row of tablets. As for the copied parts, we apply Fourier transformation to the distribution of each color and apply a low pass filter. We propose similarity index of a pattern in low frequency region based on relative perceptual difference of colors, namely, Euclid distance in $L^*a^*b^*$ color system. Besides, we propose the similarity index for displacement of the copies.

As an experiment, we calculated the distances for the PTP sheet designs of medical drugs in the market, investigated the distribution of the distances and searched the designs that had short distance to randomly selected input designs.

2. Method

Let W denote the width of original PTP sheet and H its height. If the PTP sheet has N rows of tablets, under the assumption that the PTP sheet is the union of the parts assigned to each row of tablets, the height of each part is given as $h = H/N$.

Then, we can define the RGB-valued function that shows the color at the point (x, y):

$$\boldsymbol{P}(x,y) = \sum_{k=1}^{N} \boldsymbol{\rho}_k(x, y - kh), \tag{1}$$

where $\boldsymbol{\rho}_k(x,y)$ is a vector value function that defines the color at the point (x,y) in the k^{th} part $(k = 1, 2, \dots)$. Note that the domain of the function $\boldsymbol{P}(x,y)$ is the rectangle, $0 \le x \le W \ and\ 0 \le y \le H$, and $\boldsymbol{\rho}_k(x,y)$ has its support in the area, $0 \le x \le W \ and\ 0 \le y \le h$.

Basically, we can assume that $\boldsymbol{\rho}_k(x,y)$ for $k > 1$ is almost the same as $\boldsymbol{\rho}_1(x,y)$, if the target PTP sheet is in pitch type printing, and we need to shift $\boldsymbol{\rho}_k(x,y)$ to make it coincide with $\boldsymbol{\rho}_1(x,y)$, if the target PTP sheet is in random type printing. However, there are the cases that the design of each part is different in some PTP sheets. We therefore generalize this idea so that our method can be applicable even for such cases.

In order to formulate this, we introduce the shift function,

$$S^{a,b}\big(\boldsymbol{f}(x,y)\big) = \boldsymbol{f}((x-a)\ mod\ W, (y-b)\ mod\ h), \tag{2}$$

where mod denotes modulo operation, and the function to measure the similarity based on template matching,

$$TM(\boldsymbol{f}(x,y),\boldsymbol{g}(x,y)) = \sum_{(x,y)} |\boldsymbol{f}(x,y) - \boldsymbol{g}(x,y)|. \tag{3}$$

Then we can measure the shift of the k^{th} part that is necessary to approximately coincide it to the 1st part:

$$(\hat{a}_k, \hat{b}_k) = \underset{(a,b)}{\operatorname{argmin}}\, TM\left(\boldsymbol{\rho}_1(x,y), S^{a,b}(\boldsymbol{\rho}_k(x,y))\right), \tag{4}$$

Using this shift for each part, we define an intermediate expression, $\boldsymbol{Q}(x,y)$, for PTP sheet design as

$$\boldsymbol{Q}(x,y) = \frac{1}{N}\sum_{k=1}^{N} S^{\hat{a}_k,\hat{b}_k}(\boldsymbol{\rho}_k(x,y)), \tag{5}$$

where $\hat{a}_1 = 0$ and $\hat{b}_1 = 0$. The reason we defined this is to absorb the aperiodicity in the designs of the parts. In our previous study, we assumed the existence of a design unit, prototile, and its periodical appearance. However this assumption is too ideal for realistic designs, In fact, in Japan, there have been the rules that PTP sheet designs need to include "Pla mark" and "Push through mark", and, recently, the designs are required to include bar codes as the countermeasure for mixing-up. There are the designs where these marks do not appear periodically. Even for such designs, periodically appearing subdivisions with dense and same color will be similarly sensed by persons, even the detail of the subdivision is different. Under this assumption, we designed the intermediate expression, Eq. (5), so that only densely colored and frequently appearing subdivisions remain and other subdivisions vanish.

In order to define the distance for the intermediate expressions, we convert the RGB-valued function, $\boldsymbol{Q}(x,y)$, to a CIE L*a*b*-valued function. This is because we can easily measure the distance of colors as Euclid distance in CIE L*a*b* color space.

We applied Fourier transformation to CIE L*a*b*-version $\boldsymbol{Q}(x,y)$. This is because we assume that the detail of design is not dominant for us to feel similar and we need to apply low-pass filter to it in order to reproduce humans' coarse graining in sight. Moreover, we need to design extension of Euclid distance in CIE L*a*b* color space that is compatible to the low-pass filter. In order to realize this, we employ the idea of Plancherel theorem to define our distance. Namely, if we have the function and its Fourier transformed function, they have the relation,

$$\mathcal{F}(f)(\omega_x,\omega_y) = \iint_{-\infty-\infty}^{\infty\infty} dxdy f(x,y) e^{-i(\omega_x x + \omega_y y)}, \tag{6}$$

and it can be shown that the following equation holds for them:

$$\iint_{-\infty-\infty}^{\infty\infty} d\omega_x d\omega_y \left|\mathcal{F}(f)(\omega_x,\omega_y)\right|^2 = \iint_{-\infty-\infty}^{\infty\infty} dxdy |f(x,y)|^2. \tag{7}$$

If $\boldsymbol{Q}_{\boldsymbol{i}}(x,y) = (L_i(x,y) \quad a_i(x,y) \quad b_i(x,y))^T$ for the i$^{\text{th}}$ PTP sheet, Eq. (7) can be applied to the difference of these as:

$$\iint_{-\infty-\infty}^{\infty\infty} d\omega_x d\omega_y \left(\left|\mathcal{F}(\delta L_{ij})\right|^2 + \left|\mathcal{F}(\delta a_{ij})\right|^2 + \left|\mathcal{F}(\delta b_{ij})\right|^2\right) = \iint_{-\infty-\infty}^{\infty\infty} dxdy \left(\left|\delta L_{ij}\right|^2 + \left|\delta a_{ij}\right|^2 + \left|\delta b_{ij}\right|^2\right), \tag{8}$$

where $\delta L = L_i(x,y) - L_j(x,y)$ and so on.

Moreover, since we need to apply low pass filter to Eq.(8), we define the normalized distance for the intermediate expressions as

$$d_{int}(P_i, P_j) = \sqrt{\frac{1}{\Omega_1 \Omega_2} \iint_{0\,0}^{\Omega_1 \Omega_2} d\omega_x d\omega_y \left(\left| \mathcal{F}(L_i) - \mathcal{F}(L_j) \right|^2 + \left| \mathcal{F}(a_i) - \mathcal{F}(a_j) \right|^2 + \left| \mathcal{F}(b_i) - \mathcal{F}(b_j) \right|^2 \right)}, \tag{9}$$

where Ω_1 and Ω_2 are the cut-off of the frequency domain.

Additional to this, we obtain a shift vector, which is an array of the shifts obtained in Eq. (4):

$$\boldsymbol{\sigma} = \left(\hat{a}_2, \hat{b}_2, \hat{a}_3, \hat{b}_3, \cdots, \hat{a}_N, \hat{b}_N \right). \tag{10}$$

Let $\boldsymbol{\sigma}^{(i)}$ denote the shift vector for i[th] PTP sheet. Since we assume that the design is periodic along x-axis, the difference of shifts along x-axis should be less than $W/2$. Therefore, if $\left| \hat{a}_i{}^{(1)} - \hat{a}_i{}^{(2)} \right| > W/2$, then we reassign the x-direction shift as $\hat{a}_i{}^{(2)} \coloneqq \hat{a}_i{}^{(2)} - W$. The distance for the shift vectors is defined as

$$d_{shift}(P_i, P_j) = \sum_{k=2}^{\min(N_i, N_j)} \sqrt{\left(\hat{a}_k{}^{(i)} - \hat{a}_k{}^{(j)} \right)^2 + \left(\hat{b}_k{}^{(i)} - \hat{b}_k{}^{(j)} \right)^2}, \tag{11}$$

If d_{shift} is zero, the shifts of parts in two PTPs are identical. The larger d_{shift} is, the more different the layout of the PTP designs are.

3. Examples

Figure 1 shows examples of PTP sheets [3]. Utilizing our method, we obtained the intermediate expressions (Fig. 2). Since the PTP design of Emilace is completely periodic, the intermediate expression clearly shows the drug name, Plastic marks, Press-through marks and so on. As for Irribow, pink coloured rectangles periodically appears, but its drug name and trade mark of its pharmaceutical company appear in the alternative position in the rectangles. Moreover, Plastic marks and Press-through marks alternatively appear. In its intermediate expression, the pink rectangle clearly appears and the drug name and trade mark overlap. This can coincide with the recognition that, regardless of the drug name and trade mark, the black subdivisions appear in the pink box.

Fig. 1. Examples of PTP sheet designs, Emilace [3] (left) and Irribow [3] (right).

Fig. 2. The intermediate expressions of Emilace and Irribow.

Their shift vectors were obtained as

$$\boldsymbol{\sigma}^{Emilace} = (64,99,0,96,64,93,255,90), \tag{13}$$

and

$$\boldsymbol{\sigma}^{Irribow} = (86,71,0,68,86,66,255,63,85,60,254,71). \tag{14}$$

These intermediate expressions and shift vectors gave us the distance $d_{int} = 209.98$ and $d_{shift} = 25.09$.

4. Experiments

4.1. Objective

In order to evaluate our method, it is important to apply our method to PTP sheets of drugs in the market and to check whether we can get PTP sheet designs similar to an input design. In this experiment, we calculated d_{int} and d_{shift} for each pair of target PTP sheet, and verify the pairs who have the short distance is similar in their designs.

4.2. Method

We downloaded 198 jpeg images of PTP sheets of tablets distributed by a Japanese pharmaceutical company [4], extracted their back faces, and excluded their edge parts from the pictures. We applied our method to them, calculated d_{int} and d_{shift} for each pair, and searched PTP sheet designs that have minimum distance to the PTP sheet randomly selected from the 198 images.

In this experiment, we resized each back face image to 512 pixels (height) by 256 pixels (width), and resized their intermediate expression image to 102 pixels (height) by 256 pixels (width). We set:

$$\Omega_1 = \frac{2\pi}{102} 10$$

and

$$\Omega_2 = \frac{2\pi}{256} 10$$

4.3. Results

We got d_{int} distribution of top 1000 pairs of the target images in Fig. 3. This shows that, though there were two leaps where $d_{int} \approx 120$ and $d_{int} \approx 130$, d_{int} almost linearly increases for $d_{int} > 130$. Moreover, we got d_{shift} distribution of top 1000 pairs (Fig. 4), in which we can see that it has a steep slope around $d_{shift} \approx 4$. Most of the pairs whose $d_{shift} < 2$ had the designs of pitch controlled printing. The correlation coefficient of d_{shift} and d_{shift} was -0.043.

As we discussed, the distance d_{int} measures the similarity of colors and basic designs frequently appearing in PTP sheets, and d_{shift} measures the similarity of displacement. The above results showed that d_{int} and d_{shift} measure independent aspects of PTP sheet designs. After this, we focused only on d_{int}, since we expect the similarity of colors and basic designs should play dominant role in PTP sheet design similarity.

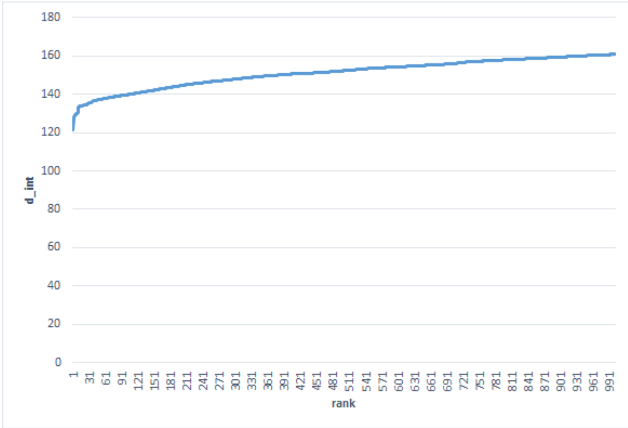

Fig. 4. Distribution of d_{int}.

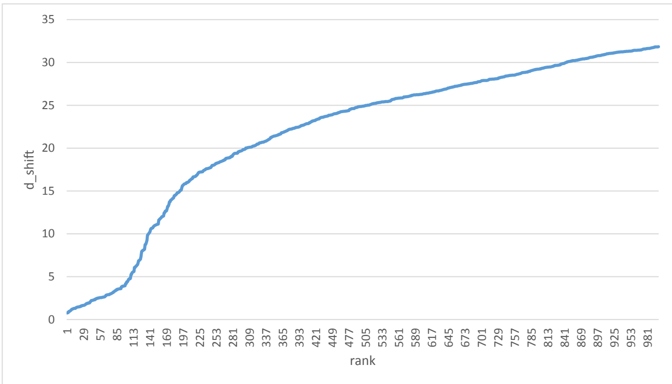

Fig. 3. Distribution of d_{shift}.

Additional to this, Fig. 3 and Fig. 4 show there were no obvious gaps that provided us with the thresholds to judge similar or not. Because of this, we used the strategy not to extract all of PTP design pairs whose distances were shorter than some threshold but to extract PTP designs whose distance to a target PTP sheet was the shortest

Then we randomly chose three PTP sheet images as target images. For each target image, we searched other three PTP sheets whose d_{int} to it were shortest (Table 1, Table 2, Table 3).

The target image in Table 1 has characteristic blue rectangles. The obtained images also have the similar rectangles in them. Obtained image #1 has the rectangle with almost same width to the target image, though #2 and #3, whose d_{int} is larger than #1, have the rectangle with slightly wider width. As for #2, the background color is different from the target image and the bar code is located at different position.

The target image in Table 2 has brown forecolor and characteristic barcodes at the 1/3 position from its top. The obtained images also have brown forecolor and barcodes in the same position.

The target image in Table 3 has characteristic green lines. The obtained images also have green forecolor. Moreover, Obtained image #1 and #3 had the similar green lines at the similar position, though #2 did not have such similar lines.

Comparing the results of the target images, we should notice that, if the ratio of forecolor part to background color part is small, d_{int} tends to have small value. This is the same situation about our study about similarity index of ampoule label designs [5]. Because of this, we should limit the use of d_{int} to search PTP sheet images which is similar to a target image.

Table 1. The images who have short distance d_{int} from the target image (1).

	Target image	Obtained image #1	Obtained image #2	Obtained image #3
Images				
d_{int}	N/A	221.8	225.5	233.3

Table 2. The images who have short distance d_{int} from the target image (2).

	Target image	Obtained image #1	Obtained image #2	Obtained image #3
Images				
d_{int}	N/A	135.6	137.9	138.8

Table 3. The images who have short distance d_{int} from the target image (3).

	Target image	Obtained image #1	Obtained image #2	Obtained image #3
Images				
d_{int}	N/A	191.0	202.6	204.1

5. Conclusion

In this study, we proposed the distances of PTP sheet designs to measure their similarities. Under the assumption that the design repeats in the direction of row, it was decomposed into the parts of repetition unit. Basically, we can assume that the parts need to be shifted to make them coincide. However, there are the cases that the design of each part is different in some PTP sheets. Because of this, we employed template matching to obtain the best matching of the parts and their shifts. After that, we defined intermediate expressions of the designs to absorb the aperiodicity in the designs of the parts. We defined two distances, d_{int} and d_{shift}, former of which is an extension of Euclid distance of the intermediate expressions in *CIE L*a*b** combining low pass filter in frequency domain, and latter of which measure the difference of the shifts.

In order to look into how our method works well, we investigated the tendency of d_{int} and d_{shift} calculated for each pair of 198 PTP designs, and searched the designs that have short distance d_{int} to randomly selected input designs.

As a result, we found that there was no characteristic in the graphs of d_{int} and d_{shift} to provide the ground of threshold selection. Moreover, for three input images, we could extract PTP sheet designs similar to the inputs. Comparing the results, it was found that, if the ratio of forecolor part to background color part is small, d_{int} tends to have small value. Because of this, it is necessary to limit the use of d_{int} to search PTP sheet images which is similar to an input image.

We should notice that, though we proposed the similarity index that is useful to find similar PTP sheet images, it does not necessarily mean the obtained PTP sheet designs are dangerous. This is because there can be many other elements, like environments, that contribute to mix-up PTP sheet.

In future work, we will establish a PTP design search engine and will propose countermeasures to prevent from mixing-up PTPs.

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